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THE PREVALENCE OF HYPERTENSION IN SCHOOL GOING ADOLESCENTS BETWEEN AGE 13 TO 19 YEARS

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INTRODUCTION

An estimated 1.4 billion people worldwide have high blood pressure with more than 9 million deaths annually but just 14% have it under control.(1) Hypertension, also known as high or raised blood pressure, is a condition in which the blood vessels have persistently raised pressure. Blood is carried from the heart to all parts of the body in the vessels. Each time the heart beats, it pumps blood into the vessels. Blood pressure is created by the force of blood pushing against the walls of blood vessels (arteries) as it is pumped by the heart. The higher the pressure, the harder the heart has to pump. (2) Hypertension is a major contributor to the global burden of disease. According to WHO, Nearly 63% of total deaths in India are due to non communicable diseases, of which 27% are attributed to cardiovascular disease. (3)

BACKGROUND

High blood pressure in children and adolescents is a growing health problem, along with the worldwide epidemics of obesity and physical inactivity. The combined prevalence of elevated blood pressure and hypertension in children is around 6%, or 3% for each. (4) High blood pressure in childhood is correlated with higher blood pressure and risk of cardiovascular disease (CVD) in adulthood, and this relationship strengthens with age. (5) The data from the National Health and Nutrition Examination Survey (NHANES) gives information on the prevalence of high blood pressure (BP) in children and is typically is based on a single BP measurement session. These surveys, conducted since 1988, indicate that there has been an increase in the prevalence of childhood high BP, including both HTN and elevated BP.(6)

The Disease

High blood pressure in children and adolescents is a growing health problem, along with the worldwide epidemics of obesity and physical inactivity. Ambulatory blood pressure monitoring should be performed to confirm hypertension in children and adolescents. Primary hypertension is now the most common cause of hypertension in children and adolescents. Primary hypertension in children is associated with other risk factors for CVD, including hyperlipidemia and insulin resistance. Children also experience target organ damage from hypertension, including left ventricular hypertrophy and pathologic vascular changes (i.e., carotid intima-media thickness) (7)

Blood Pressure Regulation: Blood pressure (BP) is regulated by a complex interplay of various physiological mechanisms. It is a complex integrated response involving a variety of organ systems including the central nervous system (CNS), cardiovascular system, kidneys, and adrenal glands. The primary factors involved in BP regulation include cardiac output (the amount of blood the heart pumps) and peripheral vascular resistance (the resistance to blood flow in the arteries). The product of cardiac output (CO) and total peripheral resistance (TPR) determines the mean arterial BP level. Heart rate is governed by β-1 and cholinergic receptors under the control of sympathetic and parasympathetic stimulation, respectively. (8)

SIGNS AND SYMPTOMS

Pathophysiology

Hypertension, or high blood pressure, in adolescents is a concerning health condition that can have long-term consequences if left untreated. It is essential to understand the pathophysiology of hypertension in adolescents to effectively manage and prevent complications. Here is a detailed explanation of the pathophysiology of hypertension in adolescents:

Developmental Changes: During adolescence, the body undergoes significant changes in terms of growth and development. Hormones like growth hormone and sex hormones influence these changes. In some cases, these hormonal fluctuations can affect blood pressure regulation.

Primary Hypertension: In many cases, hypertension in adolescents is categorized as primary or essential hypertension, which means there is no identifiable underlying cause. This type of hypertension is often associated with lifestyle factors, including poor diet, lack of physical activity, obesity, and genetics.

Obesity: One of the most common risk factors for hypertension in adolescents is obesity. Excess body fat, especially around the abdomen, can lead to an increase in the release of inflammatory cytokines and hormones from adipose tissue. These substances can disrupt normal blood pressure regulation. Various mechanisms have been suggested for obesity related hypertension and these include insulin resistance, sodium retention, increased sympathetic nervous system activity, activation of renin-angiotensin-aldosterone system (RAAS), and altered vascular function. Probable reasons for activation of the sympathetic nervous system in obesity include hyperinsulinemia and/or insulin resistance; leptin, adiponectin or other adipokines; renin-angiotensin; and

lifestyle factors. Obesity-related hypertension is associated with renal sodium retention and impaired pressure natriuresis. Circulating adiponectin levels are decreased in obesity-induced insulin resistance, and some studies suggest that adiponectin is protective against hypertension through an endothelial dependent mechanism.(9) Weight gain is associated with increases in arterial pressure, and it has been estimated that 60-70% of hypertension in adults is attributable to adiposity. (10)

Insulin Resistance: Obesity is also linked to insulin resistance, a condition where the body's cells do not respond effectively to insulin. Insulin resistance can lead to increased sodium retention by the kidneys and increased sympathetic nervous system activity, both of which contribute to elevated blood pressure. Insulin resistance and hyperinsulinemia appear to develop in obese children at an early age. The relationship between insulin sensitivity and systolic blood pressure is evident early in life. Approximately 50% of adult patients with essential hypertension, both treated and untreated, appear to be insulin resistant.(11) The pancreatic b-cell response with an intention to maintain normal glucose homeostasis in an individual with adipose tissue and muscle insulin resistance results in augmenting the risk of developing essential hypertension.(12) The other probable reasons by which insulin resistance and/or hyperinsulinemia may increase the blood pressure include an anti-natriuretic effect of insulin, increased sympathetic nervous system activity, augmented responses to endogenous vasoconstrictors, altered vascular membrane cation transport, impaired endothelium dependent vasodilatation and stimulation of vascular smooth muscle growth by insulin.(10)

Sympathetic Nervous System Activity: The sympathetic nervous system (SNS) plays a crucial role in regulating blood pressure. Increased sympathetic activity can cause blood vessels to constrict, leading to higher peripheral vascular resistance and increased blood pressure. The SNS plays a pivotal role in the regulation of vascular tone. It modulates CO and peripheral vascular resistance, the two determinants of BP. Heart rate and stroke volume are increased, at least in the early, labile phase of BP increase, and at least part of the increased vascular resistance of the established phase of hypertension may be caused by the increased sympathetic tone. (8) Any defect in the SNS, whether genetic or pathological will lead to dysregulation of blood pressure thereby causing hypertension.

Endothelial Dysfunction: The endothelium is the inner lining of blood vessels which plays a vital role in maintaining vascular health. The blood vessels are under constant mechanical loading from blood pressure and flow which cause endothelial shear stress and circumferential wall stress.[48] In addition to the morphological changes of endothelium and the vessel wall, the same mechanical forces also trigger some biochemical and biological events.[48] The normal endothelium responds to hemodynamic forces and biochemical signals from the blood by synthesizing and releasing vasoactive substances. [48] Endothelial dependent flow-mediated vasodilation is predominantly modulated by endothelium-derived nitric oxide, which stimulates soluble guanylyl cyclase activity in vascular smooth muscle cells. In adolescents with hypertension, the endothelium may become dysfunctional, leading to impaired vasodilation and increased vascular stiffness.

Renin-Angiotensin-Aldosterone System (RAAS): This biological system is a multi enzymatic cascade in which angiotensinogen, its major substrate, is processed in a 2-step reaction by renin and Angio-converting enzyme (ACE), resulting in the sequential generation of Angio I and Angio II. Along with its importance in maintaining normal circulatory homeostasis, abnormal activation of the RAS can contribute to the development of hypertension and target organ damage. (13) This hormonal system is involved in blood pressure regulation. Activation of RAAS can lead to increased sodium and water retention by the kidneys, which can contribute to hypertension. This HTN resulting from hormonal excess usually accounts for a relatively small proportion of children with secondary HTN. The regulation of sodium excretion by the kidney and consequent effects on body fluid volumes made up the critical pathway determining the chronic level of intra-arterial pressure. (13)

Inflammatory Pathways: Chronic inflammation in the body can also contribute to hypertension. Inflammatory molecules can cause blood vessels to constrict and damage the endothelium, further elevating blood pressure.

Genetic Factors: Some adolescents may have a genetic predisposition to hypertension, which can be exacerbated by environmental factors like diet and lifestyle choices. An estimated 30– 60% of the variation in blood pressure between individuals, after adjustment for age and sex, is attributed to the effect of genetic factors.(8) All of these genes are either mediating or involved in the regulation of renal sodium transport.(14) These mutations alter the blood pressure through a common pathway, changing salt and water re-absorption in the kidney. Genetically mediated alterations in the regulation or expression of renal ion channels and transporters may also be important in the genesis of hypertension. A child with a history of hypertension in both parents, and who has a sibling with hypertension, has a 40–60% chance of developing hypertension as an adult. If the sibling is a monozygotic twin, the risk of the same increases to 80%.(15)

Secondary Hypertension: In a minority of cases, hypertension in adolescents can be secondary to an underlying medical condition such as kidney disease, hormonal disorders, or heart conditions. Renal disease and renovascular disease are among the most common secondary causes of HTN in children.(16) Coarctation of the aorta is a congenital abnormality of the aortic arch characterized by discrete narrowing of the aortic arch, generally at the level of the aortic isthmus. It is usually associated with HTN and adolescents may be treated with angioplasty or stenting. Patients with coarctation can remain hypertensive or develop HTN even after early and successful repair, with reported prevalence varying from 17% to 77%.(17) The causes of secondary hypertension vary with age. Renal disorders and coarctation of the aorta are the most common causes of hypertension in children up to age 6 y. In older children, renal parenchymal disease remains the most frequent

cause of increased blood pressure. Other causes of hypertension in children are relatively rare and include systemic arteritis and certain tumours, endocrine dysfunction, and neurologic disorders.(9)

In summary, the pathophysiology of hypertension in adolescents is multifactorial and often involves a combination of genetic, lifestyle, and hormonal factors. Understanding these underlying mechanisms is crucial for healthcare providers to make accurate diagnoses and develop appropriate treatment plans, which may include lifestyle modifications, medication, and addressing any underlying medical conditions. Early intervention and management are essential to prevent long-term cardiovascular complications associated with hypertension.

Risk Factors

The reasons for the increase in blood pressure are attributed to obesity, change in food habits, decreased physical activity and increasing academic stress. The risk factors can be classified under two categories: ***Modifiable risk factors and Non-modifiable risk factors.***

Modifiable risk factors refer to aspects of an individual's lifestyle, behaviour, or environment that can be altered or changed to reduce the risk of a particular health condition or disease. These factors are within a person's control and can be influenced through various interventions such as lifestyle modifications, dietary changes, exercise, medication, or other preventive measures. Modifiable risk factors for hypertension include unhealthy diets (excessive salt consumption, a diet high in saturated fat and trans fats, low intake of fruits and vegetables), physical inactivity, consumption of tobacco and alcohol, and being overweight or obese.

Non-modifiable risk factors are characteristics or factors that contribute to an individual's risk of developing a particular health condition or disease but cannot be changed or altered through personal actions or interventions. These risk factors are typically inherent to an individual's genetic makeup, age, sex, race, or certain pre-existing medical conditions. Non modifiable risk factors often play a significant role in a person's susceptibility to various diseases, and while they cannot be modified, they are still important to consider for understanding and managing overall health risks. Non-modifiable risk factors for hypertension include a family history of hypertension, age over 65 years and co-existing diseases such as diabetes or kidney disease.

Classification

After the 2004 report "Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents" (Fourth Report)(18), interest in adolescent hypertension had increased. Normal and elevated blood pressure values for children one to 12 years of age are based on the normative distribution of blood pressure in healthy children of normal weight and are interpreted based on age, height, and sex. The AAP guideline includes suggested screening thresholds and percentile-based diagnostic tables. Absolute blood pressure values are used beginning at 13 years of age. For these adolescents, elevated blood pressure is defined as a blood pressure of 120 to 129 mm Hg systolic and less than 80 mm Hg diastolic, and hypertension is defined as blood pressure of 130/80 mm Hg or higher.(16)

In 2017, the American Academy of Pediatrics (AAP) updated its clinical practice guideline for the screening and management of high blood pressure in children and adolescents. The use of the new guideline demonstrated increased sensitivity in identification of hypertensive end organ damage (16)

Updated Definitions of BP Categories and Stages

For children aged 1-13 y	For children aged ≥ 13 y
Normal BP: < 90th percentile	Normal BP: < 120/< 80 mm Hg
Elevated BP: ≥ 90th percentile to < 95th percentile or 120/80 mm Hg to < 95th percentile (whichever is lower)	Elevated BP: 120/< 80 to 129/ < 80 mm Hg
Stage 1 HTN: ≥ 95th percentile to < 95th percentile + 12 mm Hg, or 130/80 to 139/89 mm Hg (whichever is lower)	Stage 1 HTN: 130/80 to 139/89 mm Hg
Stage 2 HTN: ≥ 95th percentile + 12 mm Hg, or ≥ 140/90 mm Hg (whichever is lower)	Stage 2 HTN: ≥ 140/90 mm Hg

BP = blood pressure; HTN = hypertension.

Fig 1: Updated Definitions of BP Categories and Stages for children and Adolescents (16)

A further classification of hypertension in children and adolescents is done as **Primary** (essential) or **Secondary**. Secondary hypertension has an underlying cause that is identifiable and may be treated, whereas primary hypertension is a diagnosis made of exclusion when an underlying disorder cannot be found.(19) In previous years, secondary hypertension was previously more common in children, primary hypertension now accounts for most cases of childhood hypertension.(20)

Tracking of Blood Pressure

Cardiovascular risk factor levels in childhood have been observed to track into adulthood, resulting in an increased risk of cardiovascular events later in life. Hypertension is poorly understood in its early asymptomatic stages, where development of hypertension involves complex and multiple mechanisms.(21) Among adolescents and young adults, elevated blood pressure is also associated with the presence of early atherosclerotic lesions. The initiation of high blood pressure burden starts in childhood and continues through adolescence to persist in the remaining phases of life. Data on BP tracking from childhood to adulthood demonstrate that higher BP in childhood correlates with higher BP in adulthood and the onset of HTN in young adulthood. (5)A previous study observed that individuals who were classified as having raised blood pressure by multiple measurements were more likely to remain high after 8 years.(22) The strength of the tracking relationship is stronger in older children and adolescents. Trajectory data on BP (including repeat measurements from early childhood into mid adulthood) confirm the association of elevated BP in adolescence with HTN in early adulthood (11) and that normal BP in childhood is associated with a lack of HTN in mid adulthood. (23) The importance of early blood pressure elevation and its persistence into adulthood is underscored by the fact that complications related to essential

hypertension, such as the presence of anatomic cardiovascular-renal changes, already exist in children. The importance of early blood pressure elevation and its persistence into adulthood is underscored by the fact that complications related to essential hypertension, such as the presence of anatomic cardiovascular-renal changes, already exist in children. (21)

Early Diagnosis

The 2017 AAP guidelines recommend measuring blood pressure annually beginning at three years of age and the 2016 European Society of Hypertension guidelines recommend screening every two years beginning at three years of age. (16,24) Measurements should occur at every health care encounter in children and adolescents with risk factors (i.e., those who are obese; who have known kidney disease, aortic arch obstruction, coarctation, or diabetes mellitus; or who are taking a medication known to increase blood pressure).

After identifying elevated blood pressure or hypertension, conducting a thorough medical history and physical examination becomes essential in distinguishing between primary and secondary hypertension in children. More extensive evaluation for secondary hypertension is warranted in specific cases, such as very young children, individuals within a healthy weight range without a familial hypertension history, and those displaying signs or symptoms indicative of an underlying systemic disorder among children and adolescents (16)

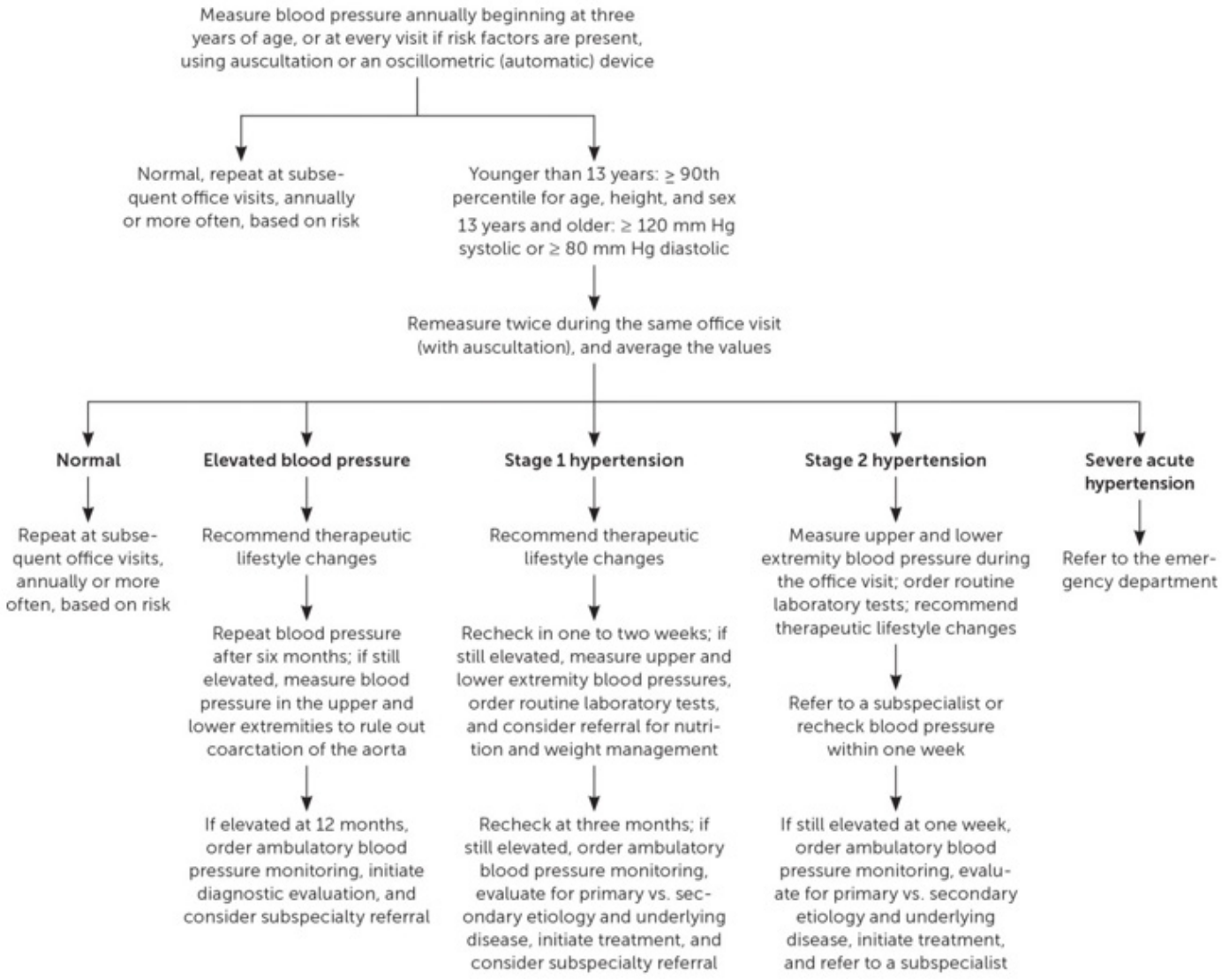

Fig 2: Algorithm for managing elevated blood pressure in children and adolescents(16)

Following the diagnosis of elevated blood pressure or hypertension, whether the child has primary or secondary hypertension can be elicited with the help of careful history and physical examination. Very young children, children or adolescents with normal weight and no family history of hypertension, and children and adolescents with signs and symptoms suggesting an additional underlying systemic disorder may be indicative towards secondary hypertension and require a more extensive work up.

Recommended Diagnostic Studies for Children and Adolescents with Confirmed Hypertension

Test	Purpose	Target population
Bilateral upper arm and single leg blood pressure measurement	Rule out coarctation of aorta	All children and adolescents
Chemistry panel, including electrolytes, blood urea nitrogen, and creatinine; urinalysis	Assess for underlying renal disease	All children and adolescents
Lipid profile	Assess for an additional cardiovascular disease risk factor	All children and adolescents
Drug screening	Rule out underlying substances contributing to or causing elevated blood pressure	Children and adolescents with history suggestive of substance use
Echocardiography (consider annually)	Assess for cardiac target organ damage	Children and adolescents in whom pharmacologic therapy is being considered
Fasting glucose or A1C level; aspartate/alanine transaminase levels	Assess for diabetes mellitus and fatty liver as additional cardiovascular risk factors	Children and adolescents who are obese
Polysomnography	Rule out obstructive sleep apnea	Children and adolescents with history suggestive of a sleep disorder
Renal ultrasonography, complete blood count	Assess for underlying renal disease	Children younger than six years and children and adolescents with abnormal renal function or urinalysis findings

Figure 3: Diagnostic studies recommended for children and adolescents with hypertension. (7)

Rationale

More people die each year from cardiovascular diseases than from any other cause. Over three quarters of heart disease and stroke-related deaths occur in low-income and middle income countries. The increasing prevalence of elevated blood pressure and hypertension among adolescents is deeply concerning, as it not only jeopardizes their immediate well-being but also sets the stage for future health challenges. Adolescence is a crucial period of development, and hypertension at this stage can have far-reaching consequences for an individual's health throughout their life course. Additionally, addressing this issue at an early age can potentially prevent or mitigate the development of hypertension-related complications in adulthood, thereby reducing the overall burden of cardiovascular diseases in society. Adolescent hardly undergo blood pressure monitoring but all adolescent should have BP monitored annually as it is a preventable cause of morbidity and mortality. One of the global targets for non communicable diseases is to reduce the prevalence of hypertension by 33% between 2010 and 2030. This study will help to promote the health and well-being of adolescents and lay the groundwork for a healthier adult population in the years to come.

Aim and Objectives

The aim of this study was to evaluate the prevalence of pre-hypertension and hypertension in school and higher secondary school in taluka place of Maharashtra.

Hypothesis

There is an increase in the prevalence of pre-hypertension and hypertension in school going adolescents.

REVIEW OF LITERATURE

The purpose of this study was to determine the prevalence of pre-hypertension and hypertension in school and higher secondary school in taluka place of Maharashtra. This chapter contains the relevant literature.

All the literature related to study topic were collected through the review of available printed documents, reports, dissertation, books, journals and articles. Internet search engines such as PubMed, Google and Google scholar were used to access the electronic resources. Keywords used for the search were adolescents, school going, pre-hypertension, elevated blood pressure, blood pressure, children, hypertension and prevalence. Literatures were obtained from the global as well as Indian context.

The studies were reviewed with studies done in India in various settings followed by the studies done around various countries in the world and the chronology of the literature review was maintained with older studies to the studies done in the recent past.

Introduction

Hypertension, commonly known as high blood pressure, is a pervasive global health issue that has traditionally been associated with the adult population Systemic hypertension is an important health problem in childhood with an estimated population prevalence of 1-2% in the developed countries. Hypertension could have its origin in childhood and go unnoticed unless specifically diagnosed during this childhood period. (25) Elevated blood pressure, defined as systolic and/or diastolic blood pressure readings consistently above the 90th percentile for age, height, and gender, is a critical precursor to hypertension. Hypertension, on the other hand, is characterized by sustained high blood pressure levels, often above 130/80 mm Hg, and can lead to a myriad of health complications, including cardiovascular diseases, stroke, and kidney problems.

Prevalence

2007. The study done by **Savitha et al.**,(26) both systolic and diastolic hypertensions were documented and 6.16% of adolescents were reported to have high blood pressure. Increased body mass index and reduced consumption of vegetables and fruits were found to be statistically significant risk factors for hypertension.

In the study conducted by **Naha NK et al.**, (25) in Kerala, the total prevalence of hypertension was found to be 4.5% and pre-hypertension was 5.85%. The children from rural area reported the prevalence of 1.01% and urban it was 7.52%. Among males, the prevalence of hypertension was found to be 4.31% and females 4.65%.

In the study done by **Mohan B et al.**,(27), Out of total 3326 students, 189 (5.6%) were found to have sustained

hypertension; it was 6.69% in urban areas and in rural area it was 2.56%. Males outnumbered females in both rural and urban areas. The mean systolic and diastolic blood pressure of hypertensive population in both urban and rural population was significantly higher than systolic and diastolic blood pressure in their normotensive counterparts.

2012. For the study conducted by **Mujumdar et al.**,(28) done to study blood pressure profile of school children in Gulbarga, Karnataka, India, 1320 children in the age group 6–15 years were selected. The prevalence of hypertension in the study was found to be 2.42% with 2.4% in females and 2.3% in males. The mean systolic and mean diastolic pressure were found to increase with increasing age and the systolic and diastolic blood pressures were slightly higher in boys than in girls.

2010. A study done in Shimla by **Avinash Sharma et al.**,(29) A total of 1085 apparently healthy students from rural and urban schools in hills of northern India were examined and those with blood pressures above the 90th centile were reexamined after four weeks. hypertension was seen in 5.9% children and prehypertension in 12.3%.

2010. A study conducted in Ahmedabad by **Khan MI et al.**,(30) on adolescent boys showed 9.78 % were found to be hypertensive and among them, 39.2 % had both systolic and diastolic hypertension. The mean SBP among the participants was 109.6 mm Hg and the mean DBP was 69.3 mmHg.

2011. School going children in Surat were studied by **Charan J et al.**, (31)and Total prevalence of hypertension was found out to be 6.48%. Hypertension in males was 6.74% and in females, it was 6.13%.

2014. **Baradol RV et al.**,(32) conducted a study in Karnataka where they found that in Rural school children, prevalence of systolic HTN was 21% in overweight children and 25% in obese children. Among urban schoolchildren prevalence of systolic PHTN was 5.1% among overweight and in obese group it was 16.6%. Prevalence of hypertension in the present study was found to be more significant in overweight and obese children as compared to normal weight children both in urban and rural population.

Associations

Goel et al.,(33) conducted a study in a district of Madhya Pradesh wherein (85.18%) had normal BMI while 69 (5.65%) adolescents were obese, and 112 (9.17%) participants were overweight. Systolic and diastolic hypertension (BP >95th percentile) was seen in 61 (4.1%) and 48 (3.9%) participants, respectively. Both systolic and diastolic hypertension was seen in 30 (2.45%) participants. Systolic and diastolic prehypertension (BP 90th to <95th percentile) was seen in 88 (7.3%) and 68 (5.6%) participants, respectively. A highly significant association ($P < 0.01$) was found with factors like sex, BMI, systolic BP, family history of hypertension, and birth weight with diastolic BP.

Raj et al., (34) examined the time trend in childhood obesity and prevalence of hypertension in 24842 students of 5-15 years of age during 2003-2004 and 20263 students during 2005-2006. The proportion of overweight children increased from 4.94% of total students in 2003 to 6.5% in 2005.

In a study done in Ludhiana, Punjab by **Mohan B et al.**,(27) overweight population was significantly higher in urban area as compared to rural Ludhiana. There was significant increase in prevalence of hypertension in both rural and urban population with increased body mass index in urban students. The students with normal BMI had prevalence of hypertension of 4.52%, it was 15.33% in overweight and in obese it was 43.10%. For students in rural area, the overweight showed prevalence of sustained hypertension in 6.82% and in obese group it was 61.76% (n=21) with no normal BMI student having hypertension.

2011. In a study done in Aligarh by **Durrani A. M. et al.**, (35) Out of 363 boys, 34 (9.36%) and out of 338 girls, 32 (9.46%) had hypertension with overall prevalence of 66 (9.4%) children. Mean systolic blood and diastolic blood pressure were higher as the range of weight, height and BMI increased and blood pressure of children showed positive correlation with anthropometrics characteristics.

2014. **Lone D et al.**,(36) conducted a study on school going children in Nagpur, central India. They found out prevalence of hypertension to be as 11.77% and an increase in anthropometric measurements like height, weight and BMI were found to be positively correlated with hypertension.

2014. **Anand T et al.**,(37) conducted a study to determine prevalence of hypertension and its correlates among adolescent in Delhi and found out 1.6% were having systolic hypertension while 5.4% were having diastolic hypertension. While 4.1% of the participants were found to be systolic pre-hypertensive, 26% were in stage of diastolic pre-hypertension. Both systolic blood pressure and diastolic blood pressure showed positive correlation with BMI, age, height and weight.

2014. **Faujdar, D. S. et al.**, (38) The study was conducted on adolescents in an urban area of Pune, belonging to upper socioeconomic group. The prevalence of hypertension was 12.23% in boys and 10.1% in girls. The mean SBP and DBP in both boys and girls were found to increase with increasing age and anthropometric measurements.

2015. **Garg et al.**, (39) Over one thousand school children were assessed in this study and overall prevalence of hypertension in this study was found out to be 9.4% (boys 9.8%; girls 9.0%). Increasing BMI and positive family history had positive correlation with increase blood pressure in these children.

2017. **Kumar P et al.**, (40) conducted study to estimate the prevalence of HT and its risk factor among apparently healthy school going adolescents of Patna district. Prevalence of HT in males was 5.0% and in females was 4.3%. Prevalence of pre-HT and HT was 10.9% and 4.6% respectively, while prevalence

of overweight/obesity was 1.5%. Both systolic and diastolic blood pressures had positive and significant correlation with age, height and body mass index.

2017. **Singh N et al.**, (41) Prevalence of hypertension among adolescents was found to be 15.3 % (14.04% among boys and 17.3 % among girls) and the prevalence of pre hypertension was 19.8% (19.0% of boys and 20.9% of girls were pre hypertensive).

METHODOLOGY

This chapter outlines the investigative methodology employed in the study. It encompasses the research design, study location, sampling procedures, techniques, and sample size determination, research tools, data collection methods, ethical considerations, and the approach to data analysis.

Study design

A community cross sectional study

Study setting

Study will be carried in government aided schools in class up to higher secondary class(12th) where most of the students come from families with agricultural background

Source population

Students from two schools between age 13 to 19 years with prior consent from school authority parents and participants.

Study population

The study population included 272 students

Selection criteria

Inclusion criteria

All healthy students willing to participate in the study.

Exclusion criteria

Students on any medications for chronic renal disorder, cardiac disorders or psychological disorders or endocrinological disorders will be excluded from the study.

Sampling procedure

Sample size

For this cross sectional study, sample size was calculated using the formula,

$$Sample\ size = \frac{Z_{1-\alpha/2^2} p\ (1-p)}{d_2}$$

Where,

$Z_1\text{-}\alpha/2^2$: standard normal variate with 5% or 1% p: expected proportion in population based on previous study or pilot study d: Absolute error or precision

$Z_1\text{-}\alpha/2^2$ is 1.96 for α= 5% and 2.58 for α= 1%

Therefore, according to data in previously published studies, actual number of hypertensives may not be more than 20%. So, the sample size for present study will be calculated as,

$$Sample\ size = \frac{(1.96)^2\ x\ 0.20\ x\ (1-0.20)}{(0.05)^2} = 246$$

The required minimum sample size for the current study was determined as 246 but all available students were recruited for the study which turned out to be 272.

Recruitment, Data collection and Tools

Data Collection

Data was collected through printed questionnaire handed over to the study subjects which included the age, sex, socio economic status, family history of hypertension, DM, dietary pattern, exercise and sleep pattern.

- The study subjects were seated in a quiet room for 3-5 minutes with back supported and feet uncrossed.
- Blood pressure was measured in right arm for consistency with arm resting at heart level, supported.
- The observer and the patient did not speak at the time of BP measurement.
- The cuff size will cover 80 to 100% arms circumference.
- If initial blood pressure was elevated that is more than 90th percentile, additional auscultatory blood pressure measurements at same visit 5 minutes apart, 3 readings were taken and average of them was taken as final reading. (16)

Variables

Blood Pressure: According to AAP CPG 2017 revised guidelines, Elevated blood pressure has replaced the term Pre-hypertension. Hypertension and Elevated blood pressure are defined as follows-(42)

	< 13 years	≥ 13 years
Normal BP	<90th percentile	<120/<80
Elevated Blood Pressure	≥ 90th to < 95th percentile or 120-129/ <80	120-129/ <80
Stage 1 HTN	≥ 95th percentile to <95th percentile + 12 mmHg or 130/80 to 139/89	130-139/ 80-89
Stage 2 HTN	≥ 95th percentile + 12 mmHg or ≥ 140/90	≥ 140/90

Body Mass Index (BMI): it will be calculated by the formula,

- BMI = weight/height2 (kg/m2)

The IAP 2015 BMI charts were used to classify the study participants. (43)

Tools

1. An Automated and validated BP machine was used. It is the new standard for HTN screening. (44)
2. A properly calibrated electronic weighing machine was used to measure the weight of all study participants. The weighing machine was kept on even ground without touching any walls. The participants were asked to step onto scale with one foot on each side of the scale, stand still with face forward. The weight was recorded upto the nearest 0.1kg.

3. BMI Charts by IAP, were referred to calculated the BMI of all study participants. (43)
4. Stadiometer for Accurate height measurement: The stadiometer being used should be calibrated and placed against a smooth wall. The participant is instructed to keep the soles of both feet positioned against the footplate, keeping thighs and knees straight. Their buttocks should lightly touch the height rod, and their arms should be naturally at their sides. The participant being measured is instructed to look straight ahead for accurate height measurement.
5. Questionnaires: Structured and pre-validated questionnaires were used.

Data analysis

Data collected from the students was analyzed using Statistical package for Social Sciences (SPSS-19). Quantitative data were analyzed using descriptive statistics in the form of frequencies, percentages, means, standard deviations and class intervals. Data analysis was based on the study objectives. Student T test is used for comparison and chi square test and Fisher's exact test was used to see the association between variables.

Ethical considerations

This was an observational study conducted with all due ethical considerations. An informed consent from parents and assent from participants was taken prior to conducting the study and administering the questionnaire. There was no monetary compensation given to any study participant. Confidentiality was ensured by using only initials of study participants and data was entered in locked excelsheet with access only to Principal Investigator. The anthropometry was done in a separate room. Those study participants who were found to have elevated blood pressure or hypertension were referred to the school physician or a Paediatrician. As the study was conducted in free time at school, there was no harm caused to their study time.

RESULTS

Gender	No of participants
MALE	114 (41.9%)
FEMALE	158 (58.1%)
TOTAL	272 (100%)

Table 1: Distribution of study subjects according to Gender

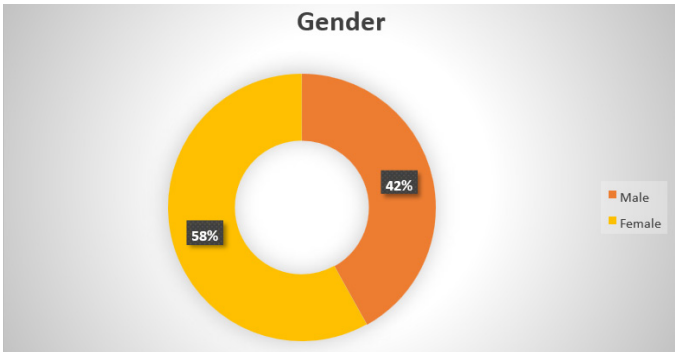

Figure 1: Distribution of study subjects according to Gender

Table 1 and Figure 1 describe the distribution of study subjects according to their gender. Out of 272 students, females (58.1%) were more than males (41.9%)

Age	No of participants
<18 Years	157 (57.7%)
18 and above	115 (42.3%)
TOTAL	272 (100%)

Minimum= 15 years Maximum= 19 years Mean=17.09±1.31

Table 2: Distribution of study subjects according to Age

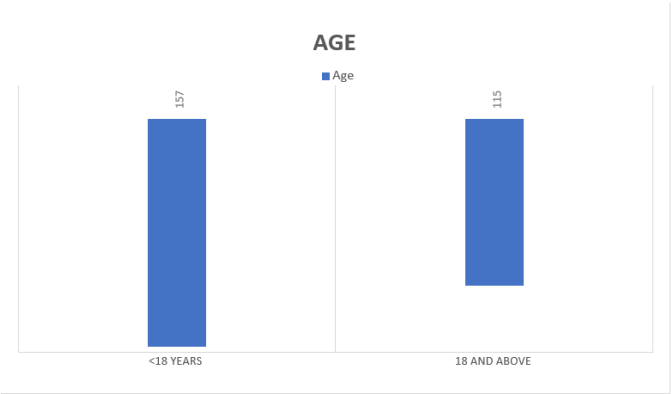

Figure 2: Distribution of study subjects according to Age

Table 2 and Figure 2 give details about the age distribution in the study participants. All study subjects belonged to the adolescent age group with minimum age being 15 years, maximum age was 19 years and mean age was 17.09±1.31 years. Out of the 272 study subjects, more were in the age group <18 years (57.7%) and remaining (42.3%) were 18 years and above.

Built	No of participants
NORMAL	150 (55.2%)
THIN/ UNDERWEIGHT	83 (30.5%)
OVERWEIGHT	27 (9.9%)
OBESE	12 (4.4%)
TOTAL	272 (100%)

Minimum= 13 Maximum= 32.20 Mean=19.2±3.28

Table 3: Distribution of study subjects according to built (BMI)

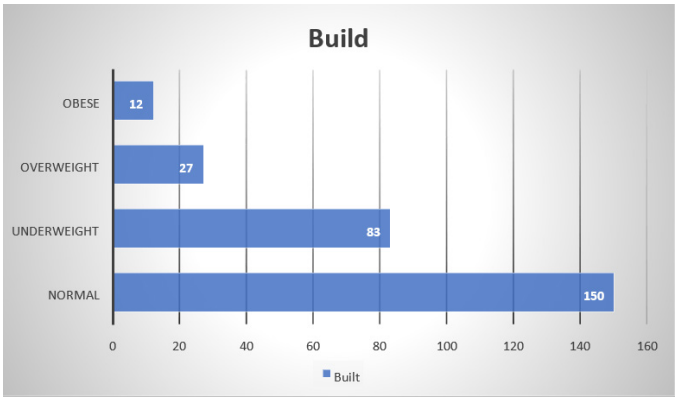

Figure 3: Distribution of study subjects according to build (BMI)

Table 3 and Figure 3 give distribution of study subjects according to their Body Mass Index (BMI) values and have been classified accordingly to their build. Among the total study participants, more than half (55%) had normal BMI levels. Out of the remaining, 86 (30.5%) were underweight (thin built), 27 (9.9%) were overweight and only 12 (4.4%) were obese.

Blood pressure levels	No of participants
NORMAL	223 (81.9%)
ELEVATED	29 (10.6%)
HYPERTENSION	20 (7.4%)
TOTAL	272 (100%)

Table 4: Distribution of study subjects according to Blood Pressure levels

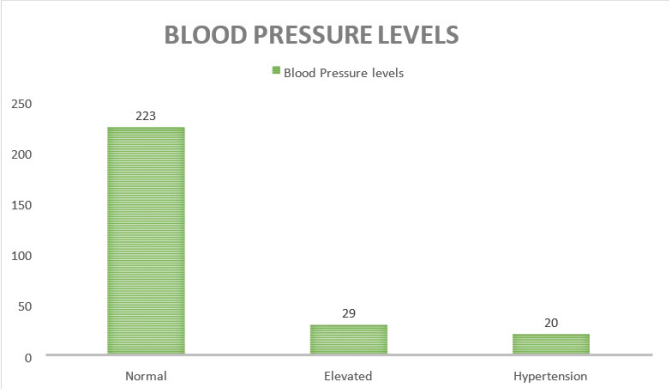

Figure 4: Distribution of study subjects according to Blood Pressure levels

Table 4 and Figure 4 shows data regarding the blood pressure levels among the study participants. The blood levels were divided into normal, elevated and confirmed hypertension as per the 2017 AAP CAG guidelines. According to the guidelines, out of the total study subjects, 29 (10.6%) students had elevated blood pressures and 20 (7.4%) were found to have Hypertension whereas 223 (81.9%) had normal levels of blood pressure.

Age	No of participants			
	Elevated Blood Pressure	Hyperten-sion	Normal	Total
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency
<18	17 (10.8)	10 (6.4)	130 (82.8)	157 (100)
18 and above	12 (10.4)	10 (8.7)	93 (80.9)	115 (100)
Total	29 (10.7)	20 (7.4)	223 (82.0)	272 (100)

***Chi-square value:** 0.528 **df:**2 **P value:**0.76*

Table 5: Association between Age of the participant and Blood Pressure

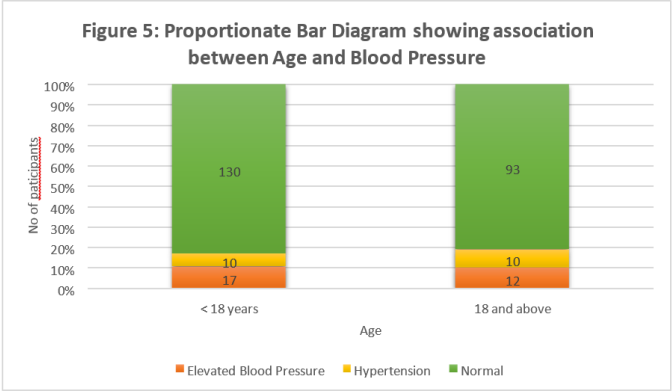

Table 5 and Figure 5 shows the association of blood pressure to the age of participants in this study. The study subjects were divided to age groups as less than 18 years and 18 years and above. Among the study participants having age <18 years, 10.8% had elevated blood pressure, 6.4% showed hypertension values and 82.8% had normal blood pressure values. The study participants who were in the category of 18 years and above had nearly similar distribution for the three categories with 10.4% students having elevated blood pressure, 8.7% having hypertension values and 80.9% having normal blood pressure levels. On statistical analysis using Chi square test, no significant difference was seen in the frequency of raised blood pressure and increasing age. [Chisq=0.528; p value=0.76]

Gender	No of participants			
	Elevated Blood Pressure	Hyperten-sion	Normal	Total
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency
Female	14 (8.9)	8 (5.1)	136 (86.1)	158 (100)
Male	15 (13.2)	12 (10.5)	87 (76.3)	114 (100)
Total	29 (10.7)	20 (7.4)	223 (82.0)	272 (100)

***Chi-square value:** 4.604 **df:**2 **P value:**0.1*

Table 6: Association between Gender of the participant and Blood Pressure (n=272)

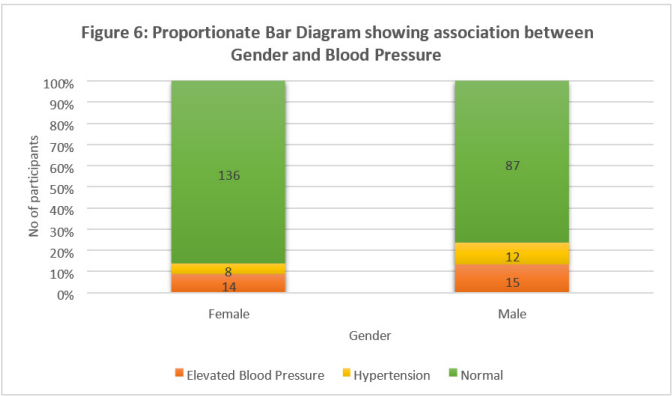

Table 6 and Figure 6 describes the association of blood pressure levels with gender of the study participants. Of the total 272 study participants, females (58%) were more than males (42%). When the blood pressure levels were seen for the two genders, males were shown to have slightly higher levels of elevated blood pressure as well as hypertension but these values were

not statistically significant. [Chisq=4.60; p value = 0.1]. Of the total females, 8.9% had elevated blood pressure, 5.1% had hypertension and 86.1% were having normal blood pressure values. Among the male participants, 13.2% had elevated blood pressure and 10.5% had hypertension with 76.3% having normal blood pressure values.

BMI	No of participants			Total
	Elevated Blood Pressure(%)	Hypertension (%)	Normal (%)	
Normal	17 (11.3)	5 (3.3)	128 (85.3)	150
Obese	3 (25)	2 (16.7)	7 (58.3)	12
Overweight	6 (22.2)	5 (18.5)	16 (59.3)	27
Underweight	3 (3.6)	8 (9.6)	72 (86.7)	83
Total	29 (10.7)	20 (7.4)	223 (82.0)	272

Chi-square value: *22.46* ***P value:****0.001*

Table 7: Association between BMI category of the participant and Blood Pressure (n=272)

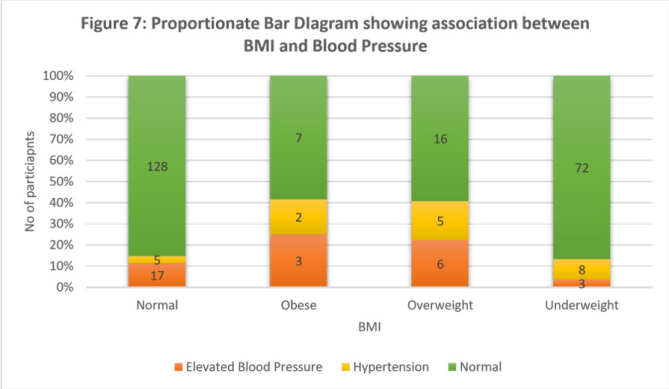

Table 7 and Figure 7 depicts the association between blood pressure levels and the BMI categories of the study participants. It was seen that with an increase in the BMI (and build), there was an increase in the number of study participants having higher levels of blood pressure i.e. elevated blood pressure and hypertension. The association when seen statistically was found to be significant. (Pearson's Chisq test value=22.46; p value=0.001)

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
AGE	272	15.0	19.0	17.092	1.3123
BMI	272	13.00	32.20	19.2085	3.28817
SBP	272	81	147	109.24	11.896
DBP	272	44.0	96.0	67.474	8.9887

The mean age of study participants in the current study is 17.09 ± 1.31 years, minimum age being 15 years and maximum age being 19 years. The average body mass index (BMI) for these study participants is 19.2 ± 3.28 kg/m^2, minimum BMI being 13 kg/m2 and maximum being 32.2 kg/m^2. The mean systolic blood pressure (SBP) was seen to be 109.24 ± 11.89 mm/Hg, with 81 mm/Hg and 147 mm/Hg as the lowest and highest values respectively. The mean diastolic blood pressure (DBP) 67.47 ± 8.98mm/Hg with 44 mm/Hg and 96 mm/Hg as the lowest and highest values respectively.

DISCUSSION

Epidemiological transition with increasing burden of cardiovascular risk factors is evident not only in adults but also in children. Hypertension is one of the major morbidity factors emerging not only in adults but the adolescent age group as well.

The roots of hypertensive cardiovascular disease (CVD) can be traced back to early childhood, where elevated blood pressure (BP) levels during childhood and adolescence serve as predictive indicators of an elevated risk of hypertension in adulthood. This heightened blood pressure substantially augments the likelihood of developing cardiovascular and cerebrovascular diseases Numerous studies conducted in various populations consistently demonstrate an age-related increase in blood pressure. The subtle and gradual progression of hypertension in adults suggests that it might have originated during childhood and adolescence (referred to as the 'tracking phenomenon'), potentially going unnoticed or undetected.

This was the focus of our current study, to determine prevalence of not only hypertension but also elevated blood pressure (which precedes hypertension) in the adults of tomorrow viz., the adolescents.

Sociodemographic

The current study reports higher female population as compared to males in the study group. Similar findings were seen in studies done in different parts of world (45) as well as India(46). Some of the other studies in India (33,36) reported nearly equal gender distribution in the study participants. Other studies from Bhopal and Delhi, (41,47) reported higher percentage of males as compared to females.

The mean systolic blood pressure (SBP) in the present study was 109.24 ± 11.89 mm/Hg and mean diastolic blood pressure (DBP) was 67.47 ± 8.98mm/Hg. **Khan M I et al.**,(30) also reported the mean SBP among the participants as 109.6 mm Hg and the mean DBP as 69.3 mmHg for boys in a school. **Singh N et al.**, (41) also reported similar mean values for SBP and DBP in their study, the overall the mean SBP was 119.7mm of Hg and mean DBP was 75.5mm of Hg with males having higher mean values than females. **Lone et al.**, (36) reported age wise mean SBP and DBP which were also in line with the values found in current study. **Garg et al.**, (39) also reported age wise mean SBP and DBP values as well as gender wise values. Their mean SBP values were similar to the values found in this study but mean DBP values were higher than in the present study. **Manjusha et al.**, (33) in their study reported mean SBP values for males and females with no significant difference, the mean DBP values on the other hand had significant difference between males and females, being higher in males than females. **Jaiswal**

et al., (46) also reported no significant in mean SBP and DBP values for boys and girls. In the study by **Vasudevan A et al.**, (48) the mean SBP and DBP was higher by almost 2 mm Hg in older compared with younger children. The SBP was lower in girls by 2.0 mm Hg compared with boys in the older age group. However, DBP was comparable between both sexes and in both age groups.

In the current study, majority of study subjects had normal body mass index (BMI), a small percentage were underweight (30.5%) and even smaller number were overweight (9.9%) or obese (4.4%). **Khan M I et al.**,(30) also reported 10.44 % to be overweight 5.77 % as obese which were closer to our values, according to the BMI percentile criteria, however they had a lower percentage of underweight 4.48% than our study. This may be due to the fact that the boys belonged to a private school and might have better nutrition owning to higher socioeconomic status. In the study conducted by Lone et al., (36) more children were having normal BMI with only 7.11% children were overweight and obese and the remaining 13.56% were underweight. **Shah et al.**,(49) had also reported similar results in the prevalence of overweight and obesity to be 9.25% and 5.55% respectively in an urban area of Bhavnagar city, Gujarat. In developed countries such as the USA, the prevalence of obesity and overweight in school children has been reported to be as high as 22% and 28%, respectively. (50) This difference might due to be the different dietary and lifestyle factors of the participants.

Childhood obesity is linked to a higher likelihood of developing hypertension, diabetes, coronary artery disease, osteoarthritis, and an elevated risk of morbidity and mortality in adulthood While the connection between childhood obesity and hypertension has been acknowledged, it has received comparatively less comprehensive exploration. Elevated blood pressure in obese children can be attributed to factors such as heightened cardiac output, excessive sodium consumption, increased steroid production, and alterations in receptors for various pressure-regulating substances (51)

The blood pressure levels in present study were found to be normal for majority of the study participants, leaving 10.6% having elevated blood pressure and 7.4% having hypertension. A study in Ludhiana, Punjab (27) on school going children reported the prevalence of sustained hypertension among rural and urban areas as 5.7% and 8.4%, respectively. A study in Kerala(25) had results similar to our study, with total prevalence of hypertension as 4.5% and Pre-hypertension as 5.8 %. Urban school children with hypertension were 7.52% and pre hypertension in urban school children were 9.4%. **Garg et al.**, (39) also reported overall prevalence of hypertension in their study as 9.4%. Manjusha et al., in a study done in central India, reported 4.9% and 7.3% of the cases having systolic hypertension and prehypertension, respectively, as against 3.9% and 5.6% participants having diastolic hypertension and prehypertension, respectively with over pre-hypertension at 11.65%, hypertension at 2.45% and normal blood pressure levels in 85.9%. In a meta analysis study (52) done in India for prevalence of hypertension in adolescents, prevalence of hypertension across studies ranged from 2% to 20.5%, with a pooled estimate of 7.6% (95% CI: 6.1 to 9.1%), I2 = 96.6% (p value <0.001). In another study done in a randomly selected school in central India, (36) the overall prevalence was found to be 11.77% which is one of the highest results shown in India. Similar to the previous study, a study in Bhopal(41) also showed prevalence of hypertension among adolescents to be 15.3 % and the prevalence of pre hypertension as 19.8%. In Iran, (45) 11.1% of boys and 11.3% girls were confirmed for hypertension in stages 1 and 2 based on the AAP guidelines. In a US study done by **Goulding M et al.**,(6) containing data from National Health and Nutrition Examination Survey (NHANES) collected from 2011 through 2018, 7.2% (95% CI, 6.3%–8.3%) of US children had elevated BP, and 3.8% (95% CI, 3.3%–4.5%) had hypertensive BP according to 2017 AAP guidelines. For the year 2017–2018, the prevalence of elevated BP was 6.2% (95% CI, 4.2%–9.3%) and the prevalence of hypertensive BP was 3.9% (95% CI, 2.9%– 5.3%). These values are slightly lesser than the values seen in this study, this may be due to better preventive care available and efficient tracking in the developed countries.

There was no significant difference seen in the frequency of raised blood pressure with increasing age in the current study. Among the study subjects having age <18 years 10.8% had elevated blood pressure, 6.4% showed hypertension values whereas participants with age 18 and above 10.4% students having elevated blood pressure, 8.7% having hypertension values. As age increased there was also an increase in the percentage of hypertension among adolescents. Other studies have also reported an increase in the prevalence of elevated blood pressure and hypertension as the age of children increases. **Faujdar et al.**, (38) in Pune reported that the mean SBP and DBP in both boys and girls were found to increase with increasing age and anthropometric measurements. Garg et al., (39) also reported an increase in mean blood pressure with the increase in age. Gupta VK et al., (25) in their study also reported the increase in prevalence of hypertension and pre-hypertension as age advances. The tendency of the blood pressure to rise with age is supported by the findings from a Turkish study among the age group of 13-18 years (53) and a study on Zambian school children (7-16 years) (54)

Males in the current study were seen to have higher values for blood pressure with more of them having elevated blood pressure and hypertension respectively. 13.2% males and 8.9% females had elevated blood pressure levels whereas 10.5% males and only 5.1% females had hypertension among the study participants. **Khan M I et al.**,(30) reported 9.78 % boys having hypertension in schools of Ahmedabad Municipal Corporation, highest prevalence was found at 19 years of age (21.7 %) and 39.2 % had both systolic and diastolic hypertension. In a study done in central India (55), prehypertension was detected in less participants as compared to current study i.e., 6.9% and 6.5% of boys and girls, respectively, whereas hypertension was found in 6.8% (Stage I: 6.7%; Stage II: 0.1%) of boys and 7.0% (Stage I: 6.6%; Stage II: 0.3%) of girls. Another study in Pune (38) also reported higher percentage in males than females with prevalence of hypertension was 12.23% in boys and 10.1%

in girls. In another study done in a randomly selected school in central India,(36) boys and girls having almost similar and higher prevalence which is 11.79% and 11.76% respectively. In a study done by **Singh N et al.**, (41) showed alternate results with prevalence of hypertension among adolescents as 14.04% among boys and 17.3 % among girls and the prevalence of pre hypertension was 19.0% of boys and 20.9% in girls.

Hypertension and obesity are interrelated conditions, often co-occurring at higher rates than in a typically healthy population. While a definitive cause-and-effect relationship hasn't been conclusively proven, their coexistence escalates the risk of cardiovascular morbidity and mortality. An increase in weight adds volume to an increase in peripheral resistance, accentuating left ventricular work that adversely affects cardiac function [(56)] In the present study, association of blood pressure levels with BMI showed an increase in blood pressure levels of study participants with an increase in the BMI values. This increase was found to be statistically significant. A study done in central India by **Goel M et al.**,(33) also showed a significant positive correlation of BMI with both systolic and diastolic BP with a gradual increase in both SBP and DBP with increasing BMI percentiles. A study in Ludhiana, Punjab (27) also showed an increase in the prevalence of hypertension in both rural and urban population with increasing BMI. The children with prehypertension and hypertension had significantly higher BMI (overweight or obesity) than their normotensive counterparts. In a study done by **Goulding M et al.**,(57) both elevated and hypertensive BP were more prevalent in children categorized as overweight or as having obesity compared with children of healthy weight. **Faujdar et al.**, also reported(38) higher prevalence of overweight as per BMI was 19.14% in boys and 18.62% in girls. The prevalence of hypertension observed in overweight children (36.1% in boys 30.8% in girls) was significantly ($p<0.000$) higher than normal weight children (6.5% in boys and 5.36% in girls) in their study. **Baradol et al.**, (32) in the study reported higher prevalence of raised blood pressure in relation to BMI in rural school children with systolic HTN in 21% of overweight children and 25% of obese children. Their overall prevalence of hypertension was far less than most studies. In other studies also done in school children (36,39) children having higher BMI, were seven times more than those having normal BMI and both SBP and DBP were higher in obese children. (54) Tracking of BMI in adolescents have high predictive value for adult obesity. The rate of increase in BMI is a good predictor of the adult level of BP, insulin resistance, hyperlipidemia, and other complications associated with obesity.

CONCLUSION

- The prevalence of elevated blood pressure was 10.6% and hypertension was 7.4% in school going adolescents.
- Increasing age and gender did not show any significant increase in the prevalence of elevated blood pressure and hypertension.
- The built of adolescents was seen to have a significant association with increased values of blood pressure with higher levels of BMI showing higher prevalence of elevated blood pressure and hypertension.

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